ERDC TN-EMRRP-RQ-01
January 2009

Applying an Avian Index of Biological Integrity to Assess and Monitor Arid and Semi-arid Riparian Ecosystems

by Michael P. Guilfoyle, James S. Wakeley, and Richard A. Fischer

PURPOSE: This technical note is a product of the Ecosystem Management and Restoration Research Program (EMRRP) work unit titled "Improving Restoration and Management of Stream and Riparian Ecosystems using a Multi-function Approach." Objectives of this work are to provide field personnel with tools and techniques to conduct rehabilitation and restoration projects that address a broad suite of functions and processes, and the tools to assess the relative success in meeting those intended goals. This technical note describes the development of an Index of Biological Integrity (IBI) for riparian ecosystems based on avian community data (Figure 1). The technique is demonstrated using data gathered in the Santa Margarita River watershed in southern California. The resulting IBI may be used to assess and monitor riparian condition in response to human land-use activities.

INTRODUCTION: Numerous factors affect ecosystem structure and function on local, regional, and global scales. While many natural processes (e.g., wind and water erosion, sedimentation, microbial and plant succession) gradually alter ecosystems over centuries or millennia (Karr 2005), human-induced alterations to the environment occur at a much greater pace. Today, many ecosystems, and the organisms they support, are being degraded or eliminated within decades rather than millennia. Human activities can result in the transformation of entire landscapes through agricultural expansion, forest management, the construction of dams, channelization and diversion of major river systems, and urban development. As a result, an ever-increasing number of species and habitats, including those considered to be endangered, threatened, or 'at risk,' are experiencing significant declines.

Figure 1. An Avian Index of Biological Integrity can be a useful tool to monitor and assess the impacts of human land use in riparian systems. Bird photos and associated copyrights for the above Bullock's Oriole (*Icterus bullockii*) (top left) and the Rock Wren (*Salipinctes obsoletus*) (bottom right) by Dr. Bradley J. Bergstrom.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JAN 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Applying an Avian Index of Biological Integrity to Assess and Monitor Arid and Semi-arid Riparian Ecosystems**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**22**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Effective tools to monitor and evaluate ecosystem change are needed to measure the impacts of human activity and determine whether ecosystem protection or restoration are needed or are even reasonable options to minimize continued degradation and loss of natural resources (Karr 1991, 2005; Karr and Chu 1999). The problem is how to accurately measure and monitor human-induced impacts in highly complex and continually changing environments.

The Index of Biological Integrity. The concept of biological integrity was first introduced in the language of the 1972 Clean Water Act. This legislation was designed to restore or maintain the physical, chemical, and biological integrity of the nation's water resources. The 1997 National Wildlife Refuge System Improvement Act further mandated government agencies to protect the biological integrity, diversity, and environmental health of the refuge system (Karr 1991, 2005; Adler 2003; Fischman 2004).

A working definition of biological integrity is "the ability to support and maintain a balanced, integrated, adaptive biological system having the full range of parts (genes, species, and assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation and fragmented population processes) expected in the natural habitat of a region" (Karr 1996). This definition incorporates the concept of scale and emphasizes that living systems range from individuals and assemblages acting locally to populations operating on the landscape or regional scale. Furthermore, living systems include not just parts of the system, but also the processes that create and maintain them. Living systems are influenced not only by the physical, chemical, and biological context of their environments, but are also subject to ongoing evolutionary processes (Karr 2005).

The complex factors impacting ecosystems need to be monitored in a hierarchical approach that includes local and regional impacts. To meet this need, a multimetric method called the Index of Biological Integrity (IBI) was developed by Karr (1981, 1987, 1991), Karr and Dudley (1981), and refined by Karr and Chu (1999). The IBI integrates numerous biological metrics to assess overall ecological conditions with data collected at the individual, population, and landscape scales (Karr 2005). Although many candidate metrics are evaluated initially, the final IBI only includes metrics that are relatively easy to measure and interpret, and that reveal noticeable biotic changes in response to human impacts (Karr and Chu 1999). Originally designed for application in aquatic and stream systems (Karr 1981, 1987; Karr and Dudley 1981), the IBI approach has since been applied to terrestrial organisms and ecosystems (Karr 2005).

Elements of an IBI. Overall objectives of the IBI approach include:

1) Monitor environmental condition and functions of an ecosystem or region.
2) Identify areas in need of protection and/or management action.
3) Provide empirical information describing baseline conditions.
4) Evaluate the effects of habitat restoration or management efforts.
5) Improve understanding of how human-induced impacts affect the ecological functions of a system.

To develop the IBI initially requires the measurement of numerous physical and biological metrics in the area or region of interest, including:

1) An Index of Human Disturbance (IHD). This index describes a gradient of disturbance from non-impacted or pristine areas to heavily impacted areas. The index reflects the magnitude of human impacts at the local and landscape scales. Data for this index can be derived from multiple sources, including Geographic Information Systems (GIS), aerial photography and satellite imagery, and on-the-ground field assessments.
2) Biological metrics describing the distribution, abundance, and species richness of one or more taxonomic groups to be monitored.
3) Functional aspects of the organisms involved, including specific habitat associations, behavioral traits, or guild structure (e.g., foraging or reproduction behavior).

Measurement of the IHD. The purpose of the IHD is to establish a gradient of human disturbance that may be negatively impacting ecological function and condition. The IHD is a single metric that may incorporate several measures of disturbance at multiple scales and provides a measure of cumulative human impacts on the ecological system being monitored. The IHD within an area should range continuously from portions with little or no human impacts to heavily disturbed areas (Karr and Chu 1999, Bryce 2006). Within watersheds or terrestrial landscapes, metrics incorporated in the IHD might include the percentage of area in agricultural lands, managed forests, cut-over lands, urban lands, etc. These percentages can be estimated at both the landscape scale from aerial photos or GIS data and local scales from field sampling (e.g., percentages of land-use categories within 100 m of selected sampling stations). The final IHD may be calculated from a composite of variables collected at the landscape and local scales; for example:

IHD = Human disturbance at landscape scale + human disturbance at local scale

The IHD can then be scaled from 0 to 100 to reflect the gradient from little or no impacts to areas heavily impacted by human land-use activities.

Measurement of Biological Metrics. Biological data are collected using standardized field methods, and are used to calculate specific metrics that may be useful components of the IBI. Biological data may include the abundance of organisms and species richness. However, relationships between organisms and the ecological conditions of their environments are often best monitored by organizing species into ecological guilds (e.g., for birds, canopy nesters, foliage gleaners, sensitive species) (Canterbury et al. 2000; O’Connell et al. 2000). Biological metrics can be calculated for each guild, and the guild metrics that respond strongly to variability in the IHD will often represent the best indicators for monitoring human impacts on the ecosystem (Karr 1987, 1996, 2005; Karr and Chu 1999).

The relationships of these metrics to the IHD are typically determined through linear regression. Regression analyses serve to identify metrics that are most sensitive to human disturbance in the study area. Biological metrics that fail to reveal any relationship to the IHD are discarded. For metrics that are highly correlated with one another ($|r| > 0.80$; e.g., abundance and species richness within a guild may be correlated), one metric may be retained while the other is removed. Also, metrics that are significantly related to the IHD, yet fail to show clear discrimination between highly impacted and non-impacted conditions, are removed.

Development of the IBI. The response of the biological metrics to the IHD is assessed using regression graphs referred to as 'dose-response curves' (Karr 1981, 1991, 1987; Karr and Chu 1999). In the creation of an IBI, it is not uncommon for dozens of biological metrics to be calculated and their relationship to the IHD assessed (Karr and Chu 1999; Bryce et al. 2002; Bryce 2006). From this assessment, usually a small subset of the biological metrics (e.g., 6-2 metrics per IBI that best explain variability in IHD) are selected according to the criteria mentioned above, and used in the formulation of the IBI for a region (e.g., Fausch et al. 1984; Miller et al. 1988; O'Connell et al. 2000; Bryce et al. 2002; Bryce 2006; Lussier et al. 2006).

Once the best biological metrics for use in the IBI are selected, the dose-response curves are examined and the range of values for each biological metric is divided into three categories. Each category is given a numeric score of 1, 3, or 5, where 1 indicates the disturbed or impacted condition, 5 represents the relatively pristine or unimpacted condition, and 3 represents an intermediate condition. This scoring process ensures that all metrics used in the final IBI will be statistically compatible, despite any differences in the original measurement units (Karr and Chu 1999), and it also allows the metrics to be ranked along a gradient of human disturbance measures (O'Connell et al. 2000). The scores for each biological metric are summed to calculate the IBI. Once developed, the IBI formula is used repeatedly to assess individual sites or to monitor changes in biological conditions or resources over time.

EXAMPLE OF AN IBI APPLIED TO BIRD COMMUNITIES IN THE SANTA MARGARITA WATERSHED, CALIFORNIA: Data recently collected in the Santa Margarita watershed in southern California were used to illustrate the development and application of an IBI (Figure 2) (Wakeley et al. 2004). Riparian habitats in the southwestern United States constitute a small fraction of the landscape but are critical to the maintenance of regional plant and animal diversity (Hubbard 1977; Szaro 1980; Brinson et al. 1981; Knopf et al. 1988). Nearly 90 percent of the original riparian habitat in the American Southwest has been lost or degraded (Dahl and Johnson 1991; Noss et al. 1995), mainly because of widespread urbanization, livestock grazing, water impoundments and diversions, and other human land-use practices (Saab et al. 1995; Rich 2002; Krueper et al. 2003).

An IBI was developed to monitor riparian reaches within the Santa Margarita watershed. Data describing avian community composition and distribution within the watershed were used to create biological metrics, which were then evaluated for potential inclusion in the IBI. Measures of bird communities (e.g., species richness, diversity, abundance) have been shown to be reliable ecological indicators that are sensitive to environmental changes and can be measured and monitored in an efficient manner (Morrison 1986; Bradford et al. 1998; Canterbury et al. 2000; O'Connell et al. 2000; Gutzwiller and Barrow 2001; Bryce et al. 2002; Rich 2002; Bryce 2006; Lussier et al. 2006).

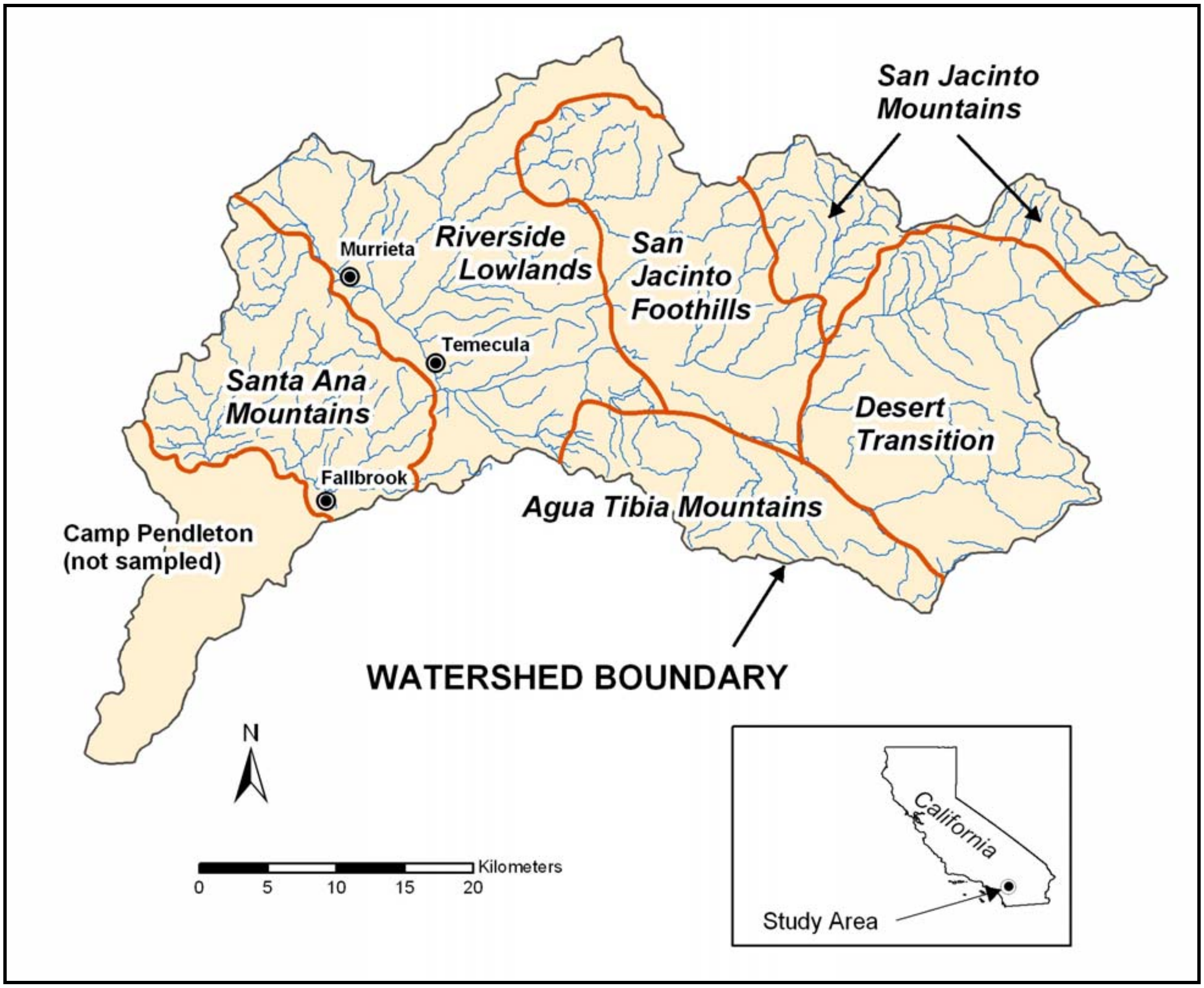

Figure 2. The Santa Margarita watershed in southern California and associated bioregions.

Study Area. The Santa Margarita watershed is approximately 174,481 ha, and is located in the western portions of Riverside and San Diego Counties, CA (Figure 2). Towns and cities in the watershed include Murrietta, Temecula, and Fallbrook. The lower reaches of the Santa Margarita River flow into the U.S. Marine Corps Camp Pendleton, which was not included in this study because of access restrictions. Elevations in the watershed ranged from approximately 107 m at Camp Pendleton to over 1,525 m in the San Jacinto Mountains in the northeastern portion of the watershed.

To facilitate sampling of bird communities, the watershed was divided into six “bioregions.” These bioregions represent different topographic and climatic conditions existing within the watershed. The bioregions were the Santa Ana Mountains, Riverside Lowlands, San Jacinto Foothills, Agua Tibia Mountains, San Jacinto Mountains, and the Desert Transition (Figure 2). For more complete descriptions of these bioregions, see Riverside County (2002) and Wakeley et al. (2004).

More than 500 riparian reaches were identified and delineated within the Santa Margarita watershed as part of a broader assessment of southern California riparian ecosystems (Smith 2003). Criteria for riparian reach designations were developed by Olson and Harris (1997) and specifically defined by Smith (2003) as “a segment of a main-stem bankfull stream channel, and the adjacent riparian ecosystem that was relatively homogenous in terms of its geological, geomorphological, edaphic, hydrological, channel morphological, vegetation, and cultural alteration characteristics.” Reaches were selected at random from within each bioregion for habitat and avian community sampling, with the restraint that the full range of human disturbance was represented. The degree of human activity within each reach was identified and ranked based on the percentage of the local drainage in developed or agricultural land uses, as indicated by spatial data developed for Riverside County (Riverside County 2002). The local drainage was defined as the area from which surface water drains into the primary channel, including associated minor tributaries that flow into this channel. Associated tributaries originate in the local drainage of the riparian reach and were linked directly to the primary channel (Smith 2003).

If a selected reach could not be assessed due to rough or inaccessible terrain, lack of landowner permission, or other logistical difficulties, another randomly chosen reach with a similar level of disturbance was substituted. A total of 96 reaches were sampled, divided as follows among the bioregions: Santa Ana Mountains (16 reaches), Riverside Lowlands (28), San Jacinto Foothills (18), San Jacinto Mountains (7), Agua Tibia Mountains (7), and Desert Transition (20).

Avian Community Sampling. Avian communities were sampled using point-counts (Hamel et al. 1996). Four point-count stations were established along each selected reach starting approximately 125 m from the downstream end. Subsequent stations were established upstream at 250-m intervals to reduce the probability of double-counting individual birds. Each station was sampled twice, with the first round of surveys conducted from March 20 through April 19, 2003, and the second round from April 20 through May 29, 2003. Each survey was conducted by a single observer in the morning, generally ending before 10:00 local standard time, to minimize time-of-day effects. Counts were not conducted during periods of high winds (>20 km) or rain (Robbins 1981). Observer-related error was minimized by using experienced technicians locally trained and familiar with the southern California avifauna (Verner and Milne 1989; Gutzwiller and Barrow 2001).

Human Disturbance Score. The IHD for the Santa Margarita watershed was estimated from indices of disturbance measured at three spatial scales:

1) **Watershed scale** - disturbance attributable to human use of the local drainage (LD).
2) **Local scale** - disturbance attributable to human use in the vicinity ($\leq$ 100 m) of the riparian reach (RR).
3) **Immediate scale** - disturbance attributable to human activity in the immediate riparian zone (RZ) (< 50 m) and within the stream channel at the survey station.

LD was calculated for each local drainage, and was based on the percentage of the drainage in developed or agricultural land uses as determined through GIS spatial data. This measurement incorporated two levels of urban development (high density or low density development), plus information on the percentage of land in agricultural use. This component of the IHD ranged

from 0-100 percent. Local drainages ranged in size from 37 to 2,440 ha; therefore, the LD metric reflected human land-use impacts at the landscape scale.

RR was determined by visually estimating human land-use patterns in a 100-m radius around each point-count station. Land uses that had the potential to impact riparian bird communities were agricultural crop or bare ground, introduced grassland or herbs (including pastures), and urban, industrial, or developed land. Percentages of these land uses were recorded in one of seven cover classes: 0, trace (<1 percent), 1-5 percent, 5-25 percent, 25-50 percent, 50-75 percent, and 75-100 percent. The disturbance score at a point was calculated by summing the midpoints of the cover classes of these land uses. The RR for a reach was determined by averaging the scores of the four sampling points. This component of the IHD ranged from 0-87.5 percent.

RZ focused on human impacts within the riparian zone or immediately adjacent areas. Human activity was estimated visually as 0 = none, 25 = light, 50 = moderate, 75 = heavy, and 100 = severe. The types of human activity included in this measurement were the use of all-terrain vehicles, dirt roads, secondary paved roads (≤2 lanes), main paved roads (≥2 lanes), livestock grazing, mowing or clearing, presence of a house or other structure, or presence of a park or picnic area. This component of the IHD ranged from 0-100 percent.

The overall IHD for each reach was calculated as:

IHD = Maximum of LD, RR, or RZ.

Data Handling and Analyses. Development of the IBI involved calculating 65 potential bird community metrics for each riparian reach in the Santa Margarita watershed, and then evaluating the relationship of each metric and the IHD across all reaches (Karr and Chu 1999, O'Connell et al. 2000). Any metric having a strong empirical relationship with the IHD was a potential component of the IBI. Three bird metrics were calculated for each of 23 groups or guilds. Metrics include:

1) Species richness (i.e., number of species of guild members)
2) Percent richness (i.e., (number of species of guild members / total number of species) × 100).
3) Percent abundance of individuals (i.e., (number of individuals birds in that guild detected / total number of birds counted in the reach) × 100).

Metrics were calculated for 23 groups or guilds based on migratory strategy, diet, foraging behavior, conservation status, riparian dependence, origin, and nesting substrate (see Appendix A). Per DeGraaf and Rappole (1995), only those species that winter primarily south of the Tropic of Cancer were classified as Neotropical migrants. Those species whose breeding and wintering ranges overlapped in the study area were counted as resident, even if considerable turnover of individuals might occur. Field guides and Birds of North America species accounts (Poole and Gill 2002) were relied on to clarify any contradictions. Non-breeders or transients were not included in analyses. Information on diet, foraging, and nest guilds were based on DeGraaf et al. (1985) and Erlich et al. (1988). Judgment was used in resolving any contradictions

found in the literature. Rich's (2002) classifications were used to categorize birds as riparian obligates, dependents, or non-dependents. Three species – House Sparrow, European Starling, and Rock Pigeon (see Appendix A for scientific names) were non-native species that now have established populations in California. All other species were native. Bird species were classified as species of conservation concern if they were:

1) Officially listed as threatened or endangered at the Federal or state level.
2) Recognized by the California Department of Fish and Game and Point Reyes Bird Observatory (PRBO) as a Bird Species of Special Concern (listed in priority lists 1, 2, or 3) *http://www.prbo.org/calpif/data.html*.
3) Classified in Tiers I or II of the Partners in Flight (PIF) priority system (Partners in Flight 2002: *http://www.blm.gov/wildlife/pifplans.htm*) (see also Panjabi 2001).

Individual metrics were evaluated first by calculating Pearson Correlation coefficients between each metric and the IHD for each reach. An analysis of variance (ANOVA) was used to check for differences in the relationship between the bird community metrics and the IHD scores across bioregions. Any bird community metric that was significantly ($P < 0.05$) correlated with the IHD was evaluated further by plotting the value of the metric versus the IHD across all sampled reaches in a bioregion or in the watershed. These ecological dose-response curves were then visually assessed to determine which bird community metrics showed the best response and good separation between relatively undisturbed and highly impacted reaches. Final metric selection was made after checking to see that none of the identified metrics was highly correlated ($|r| > 0.80$) with another selected metric. Statistical analyses were performed using SAS software (SAS Institute, Inc. 2004).

Results. Of the original 65 bird community metrics, 31 were found to be significantly related to the IHD (Table 1). The ability of the variable to show strong separation between disturbed and undisturbed riparian reaches was evaluated by visually examining the dose-response curves (Figure 3). In addition to removing highly correlated variables, any variables that did not increase the performance of the IBI were also removed. Six variables were selected for the final IBI (Tables 1 and 2; Figure 3). Scores (1, 3, or 5) for each of these six variables were determined for each sampled reach, and the IBI was calculated as the sum of these scores (Table 2). The final IBI showed a strong relationship with the IHD over the entire watershed ($r = -0.78$; $P < 0.0001$) (Figure 4).

Application. The IBI scores ranged from 6–28 (Table 2), with the lowest scores reflecting the highly disturbed conditions in the Riverside Lowlands bioregion, and the highest scores highlighting the relatively pristine riparian reaches found in the mountain bioregions and the Desert Transition bioregion (Figure 5). The IBI approach works best in regions where a distinct gradient of disturbed and pristine areas is available. While the Santa Margarita watershed IBI works well on the watershed as a whole, applicability of the approach diminishes at the scale of individual bioregions.

Table 1
Correlation Coefficients, Listed in Decreasing Order of Absolute Value, Between Bird-community Metrics and the Index of Human Disturbance (IHD) for All Sampled Reaches in the Santa Margarita Watershed (n = 96).

Bird Metric	Correlation (*r*)	*P*
Species of concern (% abundance)	-0.76	<0.0001
Exotic species (% richness) [1]	0.66	<0.0001
Exotic species richness	0.65	<0.0001
Species of conservation concern (% richness)	-0.65	<0.0001
Canopy foragers in trees and shrubs (% abundance)	-0.59	<0.0001
Canopy foragers (% richness)	-0.59	<0.0001
Granivores (% richness)	0.52	<0.0001
Native cavity nesters (% abundance)	-0.50	<0.0001
Native cavity nesters (% richness)	-0.49	<0.0001
Granivores and omnivores combined (% abundance)	0.49	<0.0001
Species of concern richness	-0.49	<0.0001
Resident species (% richness)	0.47	<0.0001
Ground foragers (% abundance)	0.46	<0.0001
Native canopy forager richness	-0.44	<0.0001
Exotic species (% abundance)	0.44	<0.0001
Neotropical migrants (% richness)	-0.43	<0.0001
Insectivores (% abundance)	-0.42	<0.0001
Granivores (% abundance)	0.41	<0.0001
Resident species (% abundance)	0.41	<0.0001
Granivore richness	0.37	0.0002
Ground foragers (% richness)	0.37	0.0002
Native cavity nester richness	-0.37	0.0003
Migrant species richness	-0.36	0.0003
Neotropical migrants (% abundance)	-0.36	0.0003
Insectivores (% richness)	-0.34	0.0008
Riparian obligates and dependents (% abundance)	-0.32	0.0016
Neotropical migrant richness	-0.32	0.0017
Granivores and omnivores combined (% richness)	0.31	0.0022
Riparian obligates and dependents (% richness)	-0.28	0.0063
Ground nesters (% abundance)	-0.24	0.0197
Insectivore richness	-0.21	0.0397

[1] Metrics in bold type were selected for the final IBI.

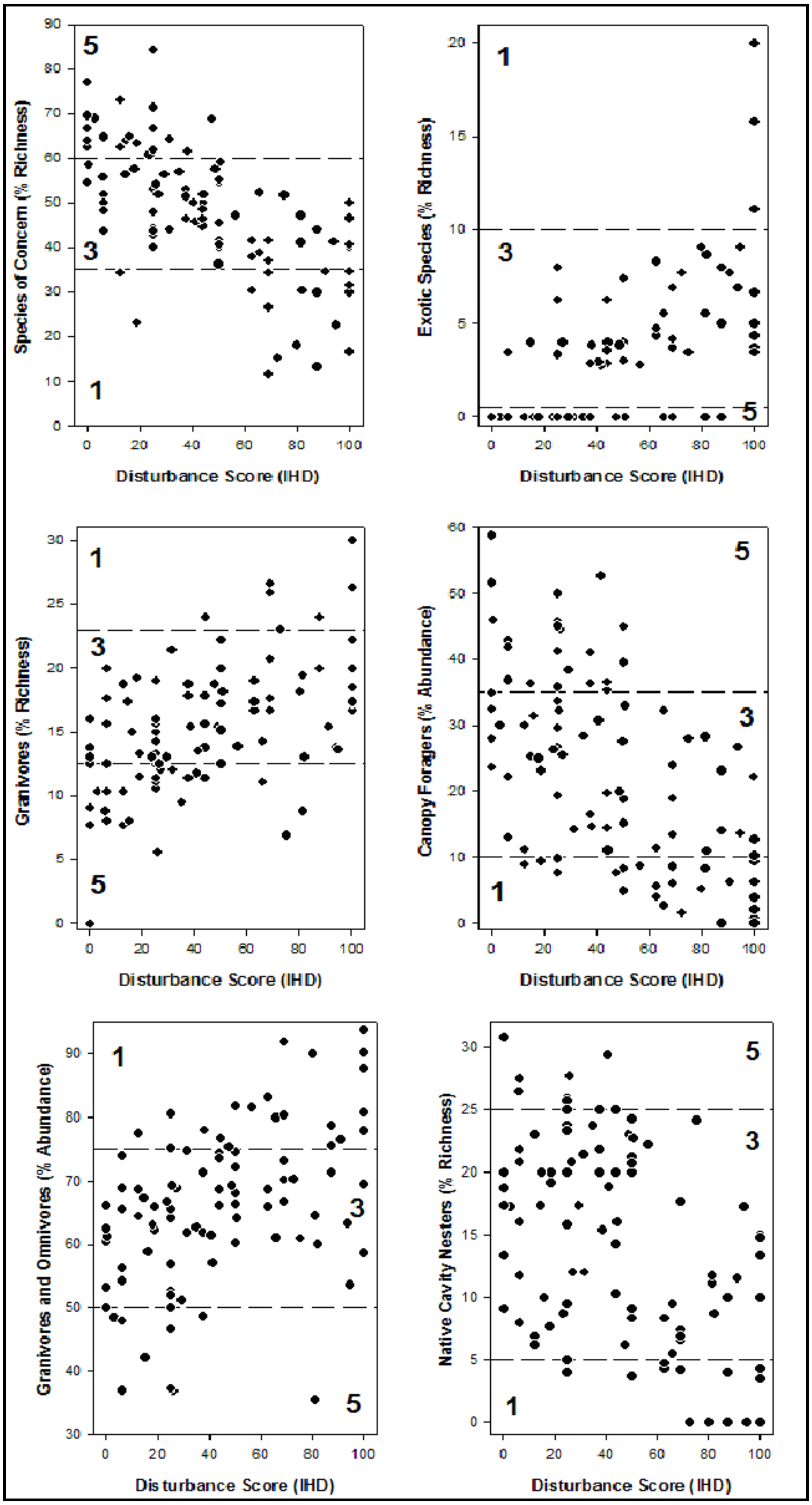

Figure 3. Dose-response curves for six significant bird community metrics used in the IBI for the Santa Margarita watershed, in southern California.

Table 2
Means and Ranges of the IBI Scores and Correlations with an Index of Human Disturbance, for Riparian Reaches in the Santa Margarita Watershed.

Bioregion (n)	IBI Scores		Correlation with Human Disturbance Index, IHD
	Mean	Range	
Riverside Lowlands (28)	14.9	6 - 24	-0.61 (*P* < 0.001)
San Jacinto Foothills (18)	19.1	14 - 22	-0.12 (*P* = 0.042)
San Jacinto Mountains (7)	23.1	14 - 28	-0.91 (*P* = 0.004)
Santa Ana Mountains (16)	22.9	14 - 28	-0.75 (*P* < 0.001)
Agua Tibia Mountains (7)	21.7	20 - 24	-0.79 (*P* = 0.036)
Desert Transition (20)	19.3	8 - 26	-0.77 (*P* < 0.001)
Total watershed (96)	19.0	6 - 28	-0.78 (*P* < 0.001)

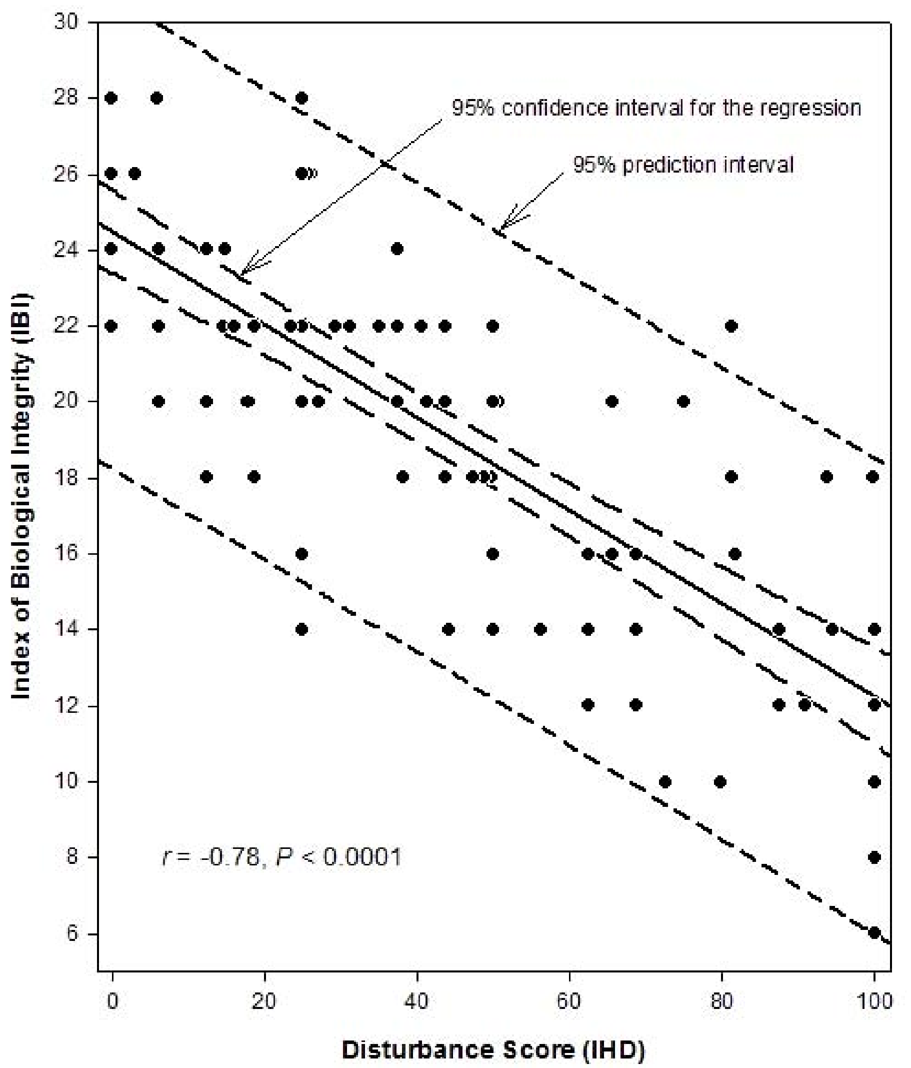

Figure 4. Graph showing the relationship between the final IBI scores for all 96 riparian reaches and IHD scores in the Santa Margarita watershed in southern California.

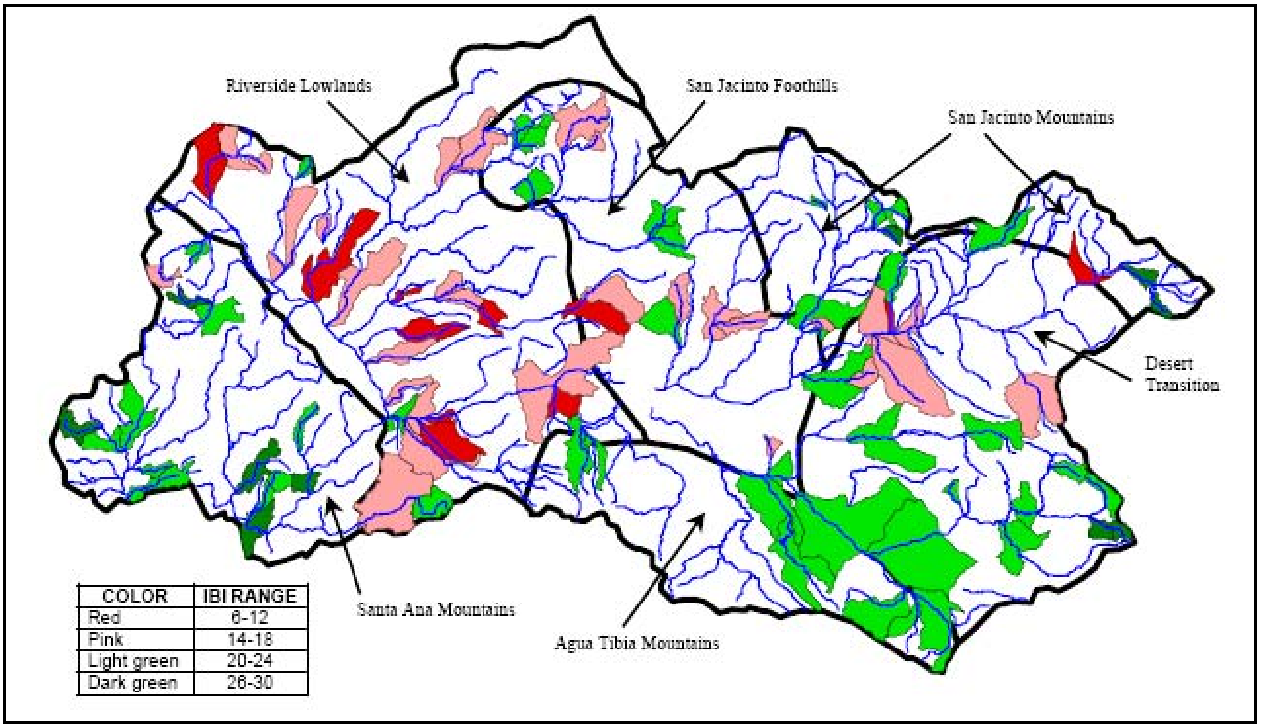

Figure 5. Distribution of color-coded IBI categories for 96 surveyed riparian reaches in the Santa Margarita watershed, southern California. Results show highest impacted reaches (lowest IBI scores in red and pink) within the Riverside Lowlands bioregion, and the most pristine reaches (highest IBI scores in light and dark green) within the Santa Ana Mountains, the San Jacinto Mountains, and the Desert Transition bioregions.

Figure 5 illustrates how the IBI scores can be utilized to obtain information on the distribution of human impacts in a watershed. From this information, managers can identify riparian areas that are in need of restoration (e.g., Riverside Lowlands) or protection (e.g., Santa Ana Mountains). Furthermore, continued monitoring of these reaches would permit managers to assess management practices within the reaches, plus identify improvements or degradations of the riparian habitats over time.

SUMMARY: This technical note describes the concept of biological integrity and describes the development and application of an Index of Biological Integrity for the purpose of monitoring complex ecological conditions on large portions of a landscape. Originally developed for aquatic systems, the IBI is a multimetric index that focuses on indicator organisms and can include both local and landscape-level measures to assess condition and health of ecological systems. The index is particularly useful to monitor changes in ecological systems brought on by human land-use practices (Karr 1987; Karr and Chu 1999).

Within the past decade, the IBI approach has been applied to riparian and terrestrial ecosystems using bird-community metrics as the primary indicator of ecological condition. This technical note provides an example of the development and application of an IBI using riparian bird communities in the Santa Margarita watershed in southern California. Riparian ecosystems in the American Southwest are subject to continuing loss and degradation due to increasingly intensive

human land use. The application of the IBI approach may also be appropriate for terrestrial and riparian habitats nationally.

The establishment of monitoring programs is essential in the management of riparian habitats. IBI scores calculated for each riparian reach reveal the distribution of impacted and pristine reaches on the landscape. Resource managers can use this approach to monitor and assess current conditions in riparian areas, develop priorities for focusing restoration and protection efforts, and evaluate success of management efforts over long periods of time.

ACKNOWLEDGEMENTS: Research in the Santa Margarita watershed was supported by the U.S. Army Corps of Engineers Los Angeles District and the U.S. Environmental Protection Agency. Development of this technical note was supported by the U.S. Army Corps of Engineers Ecosystem Management and Restoration Research Program. Technical reviews were provided by Mark Farr and Denise Lindsay, both of the U.S. Army Engineer Research and Development Center, Environmental Laboratory.

POINTS OF CONTACT: For additional information, contact the authors, Dr. Michael P. Guilfoyle (601-634-3432, *Michael.P.Guilfoyle@usace.army.mil*), Dr. James S. Wakeley, (601-634-3702, *James.S.Wakeley@usace.army.mil*) and Dr. Richard A. Fischer (502-325-6707, *Richard.A.Fischer@usace.army.mil*) or the manager of the Ecosystem Management and Restoration Research Program, Glenn Rhett (601-634-3717, *Glenn.G.Rhett@usace.army.mil*). This technical note should be cited as follows:

> Guilfoyle, M. P., J. S. Wakeley, and R. A. Fischer. 2008. *Applying an avian index of biological integrity to assess and monitor arid and semi-arid riparian ecosystems.* EMRRP Technical Notes Collection (ERDC TN-EMRRP-RQ-01). Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://el.erdc.usace.army.mil/emrrp*

REFERENCES

Adler, R. W. 2003. The two lost books in the water quality trilogy: The elusive objective of physical and biological integrity. *Environmental Law* 33:29–77.

Bradford, D. F., S. E. Franson, A. C. Neale, D. T. Heggem, G. R. Miller, and G. E. Canterbury. 1998. Bird species assemblages as indicators of biological integrity in Great Basin rangeland. *Environmental Monitoring and Assessment* 49:1–2.

Brinson, M. M., B. L. Swift, R. C. Plantico, and J. S. Barclay. 1981. *Riparian ecosystems: Their ecology and status*. FWS/OBS-81/17. Washington, DC: Fish and Wildlife Service.

Bryce, S. A. 2006. Development of a bird integrity index: Measuring avian response to disturbance in the Blue Mountains, of Oregon, USA. *Environmental Management* 38:470–486.

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: Using bird assemblages as indicators of riparian condition. *Environmental Management* 30:294–310.

Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. *Conservation Biology* 14:544–558.

Dahl, T. E., and C. E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid 1970's to mid-1980's. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service.

DeGraaf, R. M., and J. H. Rappole. 1995. *Neotropical migratory birds: Natural history, distribution, and population change.* Ithaca, NY: Comstock Publishing.

DeGraaf, R. M., N. G. Tilghman, and S. H. Anderson. 1985. Foraging guilds of North American birds. *Environmental Management* 9:493–536.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. *The birder's handbook: A field guide to the natural history of North American birds.* New York: Simon and Schuster.

Fausch, K. D., J. R. Karr, and P. R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. *Transactions of the American Fisheries Society* 113:39–55.

Fischman, R. L. 2004. The meanings of biological integrity, diversity, and environmental health. *Natural Resources Journal* 44:1003–1027.

Gutzwiller, K. J., and W. C. Barrow, Jr. 2001. Bird-landscape relations in the Chihuahuan Desert: Coping with uncertainties about predictive models. *Ecological Applications* 11:1517–1532.

Hamel, P. B., W. P. Smith, D. J. Twedt, J. R. Woehr, E. Morris, R. B. Hamilton, and R. J. Cooper. 1996. *A land manager's guide to point counts of birds in the Southeast*. General Technical Report SO-120. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Research Station, Stoneville, MS.

Hubbard, J. P. 1977. Importance of riparian ecosystems: Biotic considerations. In *Importance, preservation and management of riparian habitat*, ed. R. R. Johnson and D. A. Jones, 14-18. General Technical Report RM-43. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. *Fisheries* 6:21–27.

__________. 1987. Biological monitoring and environmental assessment: A conceptual framework. *Environmental Management* 11:249–256.

__________. 1991. Biological integrity: A long-neglected aspect of water resource management. *Ecological Applications* 1:66–84.

__________. 1996. Ecological integrity and ecological health are not the same. In *Engineering within ecological constraints*, ed. P. C. Schulze, 97-109. Washington, DC: National Academy Press.

__________. 2005. Measuring biological condition, protecting biological integrity. Article 3, companion website to M. J. Groom, G. K. Meffe, and C. R. Carroll (eds.), 2005, *Principles of Conservation Biology, 3rd ed.*, Sinauer Associates Inc., Sunderland, MA. *http://www.sinauer.com/groom/article.php?1i=3*.

Karr, J. R., and E. W. Chu. 1999. *Restoring life in running waters: Better biological monitoring.* Washington, DC: Island Press.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water quality goals. *Environmental Management* 5:55–68.

Knopf, F. L., R. R. Johnson, T. Rich, F. B. Samson, and R. C. Szaro. 1988. Conservation of riparian ecosystems in the United States. *Wilson Bulletin* 100:272–284.

Krueper, D. J., J. L. Bart, and T. D. Rich. 2003. Response of vegetation and breeding birds to the removal of cattle on the San Pedro River, Arizona (USA). *Conservation Biology* 17:607–615.

Lussier, S. M., R. W. Enser, S. N. Dasilva, and M. Charpentier. 2006. Effects of habitat disturbance from residential development on breeding bird communities in riparian corridors. *Environmental Management* 38:504–521

Miller, D. L., P. M. Leonard, R. M. Hughes, J. R. Karr, P. B. Moyle, L. H. Schrader, B. A. Thompson, R. A. Daniels, K. D. Fausch, G. A. Fitzhugh, J. R. Gammon, D. B. Halliwell, P. L. Angermeier, and D. J. Orth. 1988. Regional applications of an index of biotic integrity for use in water resource management. *Fisheries* 13:12–20.

Morrison, M. L. 1986. Bird populations as indicators of environmental change. *Current Ornithology* 3:429–451.

Noss, F. R., E. T. Laroe III, and J. M. Scott. 1995. *Endangered ecosystems of the United States: A preliminary assessment of loss and degradation.* Washington, DC: U.S. Department of the Interior, National Biological Survey.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10:1706–1721.

Olson, C., and R. Harris. 1997. Applying a two-stage system to prioritize riparian restoration at the San Luis Rey River, San Diego County, California. *Ecological Restoration* 29:243–258.

Panjabi, A. 2001. The Partners in Flight Handbook on Species Assessment and Prioritization, Version 1.1. Partners in Flight and the Rocky Mountain Bird Observatory. *http://www.rmbo.org/pubs/downloads/handbook.pdf*

Partners in Flight. 2002. Partners in Flight: Physiographic area plans. *http://www.blm.gov/wildlife/pifplans.htm* (9 Aug. 2007).

Poole, A., and F. Gill, eds. 2002. *The Birds of North America.* Philadelphia, PA: The Birds of North American, Inc.

Rich, T. D. 2002. Using breeding land birds in the assessment of western riparian systems. *Wildlife Society Bulletin* 30:1128–1139.

Riverside County. 2002. Western Riverside County Multiple Species Habitat Conservation Plan. Public Review Draft posted on the web site of the Riverside County Integrated Project. *http://www.rcip.org/draft_mshcp_2_toc.htm*.

Robbins, C. S. 1981. Bird activity levels related to weather. *Studies in Avian Biology* 6:301–310.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. In *Ecology and management of neotropical migratory birds: A synthesis and review of critical issues*, ed. T. E. Martin and D. M. Finch, 311-353. New York: Oxford University Press.

SAS Institute, Inc. 2004. SAS/STAT User's Guide, Release 9.1 Edition. Cary, NC.

Smith, R. D. 2003. Assessment of Riparian Ecosystem Integrity: San Jacinto and Upper Santa Margarita River Watersheds, Riverside County, California. U.S. Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS. Final Report to the U.S. Army Corps of Engineers, Los Angeles District.

Szaro, R. C. 1980. Factors influencing bird populations in southwestern riparian forests. In *Workshop proceedings: Management of western forests and grasslands for nongame birds*, Tech. Coord., R. M. DeGraaf, 403-418. General Technical Report NT-86. Ogden, UT: U.S. Department of Agriculture, Forest Service.

Verner, J., and K. A. Milne. 1989. Coping with sources of variability when monitoring population trends. *Annals Zoologica Fennici* 26:191–199.

Wakeley, J. S., M. P. Guilfoyle, and R. A. Fischer. 2004. Development of an index of biological integrity for riparian ecosystems in the Santa Margarita River watershed, Riverside and San Diego Counties, California. Final Report. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

APPENDIX A: LIST OF ALL SPECIES DETECTED DURING 2003 SAMPLING OF BIRD GROUPS AND GUILDS IN THE SANTA MARGARITA RIVER WATERSHED CONSIDERED IN IBI DEVELOPMENT

Species	Scientific Name	Migratory Status	Predominant Diet	Foraging Guild	Conservation Status[1]	Riparian Use	Origin	Nest Location
Eared Grebe	*Podiceps nigricollis*	Nonbreed	Crustaceavore	Water		Water bird	Native	Floating
Pied-billed Grebe	*Podilymbus podiceps*	Resident	Crustaceavore	Water		Water bird	Native	Floating
Clark's Grebe	*Aechmophorus clarkii*	Resident	Piscivore	Water		Water bird	Native	Floating
Western Grebe	*Aechmophorus occidentalis*	Resident	Piscivore	Water		Water bird	Native	Floating
American White Pelican	*Pelecanus erythrorhynchos*	Nonbreed	Piscivore	Water	PRBO 1	Water bird	Native	Ground
Double-crested Cormorant	*Phalacrocorax auritus*	Resident	Piscivore	Water		Water bird	Native	Ground
Black-crowned Night-Heron	*Nycticorax nycticorax*	Resident	Piscivore	Water		Water bird	Native	Tree
Snowy Egret	*Egretta thula*	Short Dist.	Crustaceavore	Water		Water bird	Native	Tree
Great Blue Heron	*Ardea herodias*	Resident	Piscivore	Water		Water bird	Native	Tree
Domestic Goose	*Anser domesticus*	Resident	Granivore	Ground		Captive	Introduced	Ground
Canada Goose	*Branta canadensis*	Resident	Omnivore	Ground		Water bird	Native	Ground
Mallard	*Anas platyrhynchos*	Resident	Granivore	Water		Water bird	Native	Ground
Gadwall	*Anas strepera*	Resident	Herbivore	Water		Water bird	Native	Ground
Cinnamon Teal	*Anas cyanoptera*	Resident	Granivore	Water	PIF 2A	Water bird	Native	Ground
Redhead	*Aythya americana*	Resident	Crustaceavore	Water	PRBO 2	Water bird	Native	Floating
Ruddy Duck	*Oxyura jamaicensis*	Resident	Herbivore	Water		Water bird	Native	Ground
Turkey Vulture	*Cathartes aura*	Resident	Carnivore	Ground Scavenge		Non-Dependent	Native	Cavity
Osprey	*Pandion haliaetus*	Resident	Piscivore	Water		Water bird	Native	Tree
White-tailed Kite	*Elanus leucurus*	Resident	Carnivore	Ground Hawk		Non-Dependent	Native	Tree
Northern Harrier	*Circus cyaneus*	Resident	Carnivore	Ground Hawk	PRBO 2, PIF 2C	Non-Dependent	Native	Ground
Golden Eagle	*Aquila chrysaetos*	Resident	Carnivore	Ground Hawk		Non-Dependent	Native	Cliff
Sharp-shinned Hawk	*Accipiter striatus*	Resident	Carnivore	Air		Non-Dependent	Native	Coniferous Tree
Red-shouldered Hawk	*Buteo lineatus*	Resident	Carnivore	Ground Hawk		Non-Dependent	Native	Tree
Red-tailed Hawk	*Buteo jamaicensis*	Resident	Carnivore	Ground Hawk		Non-Dependent	Native	Tree
American Kestrel	*Falco sparverius*	Resident	Insectivore	Ground Hawk	PIF 2A	Non-Dependent	Native	Cavity
Domestic Peacock	*Pavo cristatus*	Resident	Granivore	Ground		Captive	Introduced	Ground
Domestic Chicken	*Gallus gallus*	Resident	Granivore	Ground		Captive	Introduced	Ground
California Quail	*Callipepla californica*	Resident	Granivore	Ground	PIF 2B	Non-Dependent	Native	Ground
Mountain Quail	*Oreortyx pictus*	Resident	Granivore	Ground	PIF 1	Non-Dependent	Native	Ground
Sora	*Porzana carolina*	Resident	Insectivore	Ground		Marsh bird	Native	Floating
American Coot	*Fulica americana*	Resident	Omnivore	Water		Water bird	Native	Floating
Killdeer	*Charadrius vociferus*	Resident	Insectivore	Ground	PIF 2A	Non-Dependent	Native	Ground
Long-billed Dowitcher	*Limnodromus scolopaceus*	Resident	Insectivore	Water		Water bird	Native	Ground
								(Sheet 1 of 5)

Species	Scientific Name	Migratory Status	Predominant Diet	Foraging Guild	Conservation Status[1]	Riparian Use	Origin	Nest Location
Ring-billed Gull	*Larus delawarensis*	Nonbreed	Omnivore	Ground		Water bird	Native	Ground
California Gull	*Larus californicus*	Short Dist.	Omnivore	Ground		Water bird	Native	Ground
Band-tailed Pigeon	*Columba fasciata*	Resident	Granivore	Canopy	PIF 1	Non-Dependent	Native	Ground
Rock Pigeon	*Columba livia*	Resident	Omnivore	Ground		Non-Dependent	Introduced	Cliff
Mourning Dove	*Zenaida macroura*	Resident	Granivore	Ground		Non-Dependent	Native	Tree
Common Ground-Dove	*Columbina passerina*	Resident	Granivore	Ground		Non-Dependent	Native	Ground
Greater Roadrunner	*Geococcyx californianus*	Resident	Insectivore	Ground		Non-Dependent	Native	Tree
Barn Owl	*Tyto alba*	Short Dist.	Carnivore	Ground Hawk	PIF 2B	Non-Dependent	Native	Tree
Burrowing Owl	*Athene cunicularia*	Resident	Carnivore	Ground Hawk	PRBO 1, PIF 2C	Non-Dependent	Native	Burrow
Lesser Nighthawk	*Chordeiles acutipennis*	Neotropical	Insectivore	Air		Non-Dependent	Native	Ground
White-throated Swift	*Aeronautes saxatalis*	Resident	Insectivore	Air	PIF 2A	Non-Dependent	Native	Cliff
Black-chinned Hummingbird	*Archilochus alexandri*	Neotropical	Nectarivore	Flower	PIF 1	Dependent	Native	Tree
Costa's Hummingbird	*Calypte costae*	Resident	Nectarivore	Flower	PIF 1	Non-Dependent	Native	Shrub
Anna's Hummingbird	*Calypte anna*	Resident	Nectarivore	Flower	PIF 2B	Non-Dependent	Native	Tree
Allen's Hummingbird	*Selasphorus sasin*	Neotropical	Nectarivore	Flower	PIF 1	Non-Dependent	Native	Tree
Belted Kingfisher	*Ceryle alcyon*	Resident	Piscivore	Water		Obligate	Native	Bank
Acorn Woodpecker	*Melanerpes formicivorus*	Resident	Omnivore	Canopy		Non-Dependent	Native	Cavity
Northern (Red-shafted) Flicker	*Colaptes auratus*	Resident	Insectivore	Ground		Non-Dependent	Native	Cavity
Red-breasted Sapsucker	*Sphyrapicus ruber*	Short Dist.	Insectivore	Bark		Non-Dependent	Native	Cavity
Ladder-backed Woodpecker	*Picoides scalaris*	Resident	Insectivore	Bark		Non-Dependent	Native	Cavity
Nuttall's Woodpecker	*Picoides nuttallii*	Resident	Insectivore	Bark	PIF 1	Non-Dependent	Native	Cavity
Downy Woodpecker	*Picoides pubescens*	Resident	Insectivore	Bark		Non-Dependent	Native	Cavity
Hairy Woodpecker	*Picoides villosus*	Resident	Insectivore	Bark		Non-Dependent	Native	Cavity
Olive-sided Flycatcher	*Contopus cooperi*	Neotropical	Insectivore	Air	PRBO 2, PIF 2A	Non-Dependent	Native	Coniferous Tree
Western Wood-Pewee	*Contopus sordidulus*	Neotropical	Insectivore	Air	PIF 2A	Dependent	Native	Coniferous Tree
Willow Flycatcher (Southwestern)	*Empidonax traillii extimus*	Neotropical	Insectivore	Air	SE, FE	Obligate	Native	Shrub
Gray Flycatcher	*Empidonax wrightii*	Transient	Insectivore	Air		Non-Dependent	Native	Shrub
Pacific-slope Flycatcher	*Empidonax difficilis*	Neotropical	Insectivore	Air	PIF 2B	Non-Dependent	Native	Cavity
Black Phoebe	*Sayornis nigricans*	Resident	Insectivore	Air	PIF 2B	Non-Dependent	Native	Cliff
Say's Phoebe	*Sayornis saya*	Resident	Insectivore	Air		Non-Dependent	Native	Cliff
Ash-throated Flycatcher	*Myiarchus cinerascens*	Neotropical	Insectivore	Canopy	PIF 2A	Non-Dependent	Native	Cavity
Western Kingbird	*Tyrannus verticalis*	Neotropical	Insectivore	Air		Non-Dependent	Native	Tree
Cassin's Kingbird	*Tyrannus vociferans*	Short Dist.	Insectivore	Air		Non-Dependent	Native	Tree

(Sheet 2 of 5)

Species	Scientific Name	Migratory Status	Predominant Diet	Foraging Guild	Conservation Status[1]	Riparian Use	Origin	Nest Location
Loggerhead Shrike	*Lanius ludovicianus*	Resident	Carnivore	Ground Hawk	PRBO 2, PIF 2A	Non-Dependent	Native	Tree
Bell's Vireo (Least)	*Vireo bellii pusillus*	Neotropical	Insectivore	Canopy	SE, FE	Dependent	Native	Shrub
Hutton's Vireo	*Vireo huttoni*	Resident	Insectivore	Canopy	PIF 1	Non-Dependent	Native	Tree
Cassin's Vireo	*Vireo cassinii*	Neotropical	Insectivore	Canopy	PIF 2C	Non-Dependent	Native	Coniferous Tree
Warbling Vireo	*Vireo gilvus*	Neotropical	Insectivore	Canopy		Dependent	Native	Tree
Steller's Jay	*Cyanocitta stelleri*	Resident	Omnivore	Ground		Non-Dependent	Native	Coniferous Tree
Western Scrub-Jay	*Aphelocoma californica*	Resident	Omnivore	Ground	PIF 2B	Non-Dependent	Native	Tree
American Crow	*Corvus brachyrhynchos*	Resident	Omnivore	Ground		Non-Dependent	Native	Tree
Common Raven	*Corvus corax*	Resident	Omnivore	Ground		Non-Dependent	Native	Cliff
Horned Lark	*Eremophila alpestris*	Resident	Omnivore	Ground		Non-Dependent	Native	Ground
Tree Swallow	*Tachycineta bicolor*	Resident	Insectivore	Air		Dependent	Native	Cavity
Violet-green Swallow	*Tachycineta thalassina*	Short Dist.	Insectivore	Air	PIF 2A	Non-Dependent	Native	Cavity
Bank Swallow	*Riparia riparia*	Neotropical	Insectivore	Air	ST	Obligate	Native	Bank
Cliff Swallow	*Petrochelidon pyrrhonota*	Neotropical	Insectivore	Air		Non-Dependent	Native	Cliff
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Neotropical	Insectivore	Air	PIF 2A	Non-Dependent	Native	Bank
Barn Swallow	*Hirundo rustica*	Neotropical	Insectivore	Air		Non-Dependent	Native	Cliff
Wrentit	*Chamaea fasciata*	Resident	Insectivore	Canopy	PIF 1	Non-Dependent	Native	Shrub
Oak Titmouse	*Baeolophus inornatus*	Resident	Omnivore	Canopy	PIF 1	Non-Dependent	Native	Cavity
Mountain Chickadee	*Poecile gambeli*	Resident	Insectivore	Canopy		Non-Dependent	Native	Cavity
Verdin	*Auriparus flaviceps*	Resident	Insectivore	Canopy		Non-Dependent	Native	Shrub
Bushtit	*Psaltriparus minimus*	Resident	Insectivore	Canopy	PIF 2A	Non-Dependent	Native	Tree
Brown Creeper	*Certhia americana*	Resident	Insectivore	Bark		Non-Dependent	Native	Coniferous Tree
White-breasted Nuthatch	*Sitta carolinensis*	Resident	Insectivore	Bark		Non-Dependent	Native	Cavity
Red-breasted Nuthatch	*Sitta canadensis*	Resident	Insectivore	Bark		Non-Dependent	Native	Cavity
Pygmy Nuthatch	*Sitta pygmaea*	Resident	Insectivore	Bark	PIF 2B	Non-Dependent	Native	Cavity
House Wren	*Troglodytes aedon*	Resident	Insectivore	Canopy		Dependent	Native	Cavity
Bewick's Wren	*Thryomanes bewickii*	Resident	Insectivore	Ground	PIF 2A	Dependent	Native	Cavity
Cactus Wren	*Campylorhynchus brunneicapillus*	Resident	Omnivore	Ground		Non-Dependent	Native	Cactus
Rock Wren	*Salpinctes obsoletus*	Resident	Insectivore	Ground		Non-Dependent	Native	Ground
Canyon Wren	*Catherpes mexicanus*	Resident	Insectivore	Ground	PIF 2B	Non-Dependent	Native	Cliff
Marsh bird Wren	*Cistothorus palustris*	Resident	Insectivore	Ground	PIF 2C	Marsh Bird	Native	Reeds
Golden-crowned Kinglet	*Regulus satrapa*	Resident	Insectivore	Canopy		Non-Dependent	Native	Coniferous Tree
								(Sheet 3 of 5)

Species	Scientific Name	Migratory Status	Predominant Diet	Foraging Guild	Conservation Status[1]	Riparian Use	Origin	Nest Location
Ruby-crowned Kinglet	*Regulus calendula*	Nonbreed	Insectivore	Canopy		Non-Dependent	Native	Coniferous Tree
Blue-gray Gnatcatcher	*Polioptila caerulea*	Resident	Insectivore	Canopy		Non-Dependent	Native	Tree
Western Bluebird	*Sialia mexicana*	Resident	Insectivore	Ground Hawk	PIF 2B	Non-Dependent	Native	Cavity
California Swainson's Thrush	*Catharus ustulatus oedicus*	Neotropical	Insectivore	Ground	PRBO 3	Dependent	Native	Shrub
Hermit Thrush	*Catharus guttatus*	Resident	Insectivore	Ground		Non-Dependent	Native	Ground
American Robin	*Turdus migratorius*	Resident	Insectivore	Ground		Non-Dependent	Native	Tree
Northern Mockingbird	*Mimus polyglottos*	Resident	Omnivore	Ground		Non-Dependent	Native	Shrub
Sage Thrasher	*Oreoscoptes montanus*	Nonbreed	Insectivore	Ground		Non-Dependent	Native	Shrub
California Thrasher	*Toxostoma redivivum*	Resident	Omnivore	Ground	PIF 1	Non-Dependent	Native	Shrub
Crissal Thrasher	*Toxostoma crissale*	Resident	Insectivore	Ground	PRBO 1, PIF 1	Non-Dependent	Native	Shrub
European Starling	*Sturnus vulgaris*	Resident	Omnivore	Ground		Non-Dependent	Introduced	Cavity
American Pipit	*Anthus rubescens*	Short Dist.	Insectivore	Ground		Non-Dependent	Native	Ground
Cedar Waxwing	*Bombycilla cedrorum*	Nonbreed	Omnivore	Canopy		Non-Dependent	Native	Tree
Phainopepla	*Phainopepla nitens*	Resident	Frugivore	Canopy	PIF 2B	Dependent	Native	Tree
Orange-crowned Warbler	*Vermivora celata*	Resident	Insectivore	Canopy		Dependent	Native	Shrub
Nashville Warbler	*Vermivora ruficapilla*	Short Dist.	Insectivore	Canopy		Non-Dependent	Native	Ground
Yellow-rumped (Audubon's) Warbler	*Dendroica coronata*	Resident	Insectivore	Canopy		Non-Dependent	Native	Coniferous Tree
Black-throated Gray Warbler	*Dendroica nigrescens*	Neotropical	Insectivore	Canopy	PIF 2B	Non-Dependent	Native	Coniferous Tree
Townsend's Warbler	*Dendroica townsendi*	Nonbreed	Insectivore	Canopy		Non-Dependent	Native	Coniferous Tree
Hermit Warbler	*Dendroica occidentalis*	Short Dist.	Insectivore	Canopy		Non-Dependent	Native	Coniferous Tree
Yellow Warbler	*Dendroica petechia*	Neotropical	Insectivore	Canopy	PRBO 2	Obligate	Native	Shrub
Wilson's Warbler	*Wilsonia pusilla*	Neotropical	Insectivore	Canopy		Obligate	Native	Ground
Common Yellowthroat	*Geothlypis trichas*	Resident	Insectivore	Canopy		Obligate	Native	Shrub
Yellow-breasted Chat	*Icteria virens*	Neotropical	Omnivore	Canopy	PRBO 3	Obligate	Native	Shrub
Western Tanager	*Piranga ludoviciana*	Neotropical	Omnivore	Canopy		Non-Dependent	Native	Coniferous Tree
Green-tailed Towhee	*Pipilo chlorurus*	Short Dist.	Insectivore	Ground		Non-Dependent	Native	Shrub
California Towhee	*Pipilo crissalis*	Resident	Omnivore	Ground	PIF 2B	Non-Dependent	Native	Shrub
Spotted Towhee	*Pipilo maculatus*	Resident	Omnivore	Ground		Non-Dependent	Native	Ground
Rufous-crowned Sparrow	*Aimophila ruficeps*	Resident	Omnivore	Ground		Non-Dependent	Native	Ground
Chipping Sparrow	*Spizella passerina*	Resident	Omnivore	Ground		Non-Dependent	Native	Coniferous Tree
Brewer's Sparrow	*Spizella breweri*	Resident	Insectivore	Ground		Non-Dependent	Native	Shrub
Lark Sparrow	*Chondestes grammacus*	Resident	Omnivore	Ground		Non-Dependent	Native	Ground
Black-chinned Sparrow	*Spizella atrogularis*	Short Dist.	Omnivore	Ground	PIF 1	Non-Dependent	Native	Shrub

(Sheet 4 of 5)

Species	Scientific Name	Migratory Status	Predominant Diet	Foraging Guild	Conservation Status[1]	Riparian Use	Origin	Nest Location
Black-throated Sparrow	*Amphispiza bilineata*	Resident	Insectivore	Ground		Non-Dependent	Native	Shrub
Sage Sparrow	*Amphispiza belli*	Resident	Insectivore	Ground		Non-Dependent	Native	Shrub
Grasshopper Sparrow	*Ammodramus savannarum*	Short Dist.	Insectivore	Ground	PRBO 2	Non-Dependent	Native	Ground
Fox Sparrow	*Passerella iliaca*	Short Dist.	Insectivore	Ground		Obligate	Native	Ground
Savannah Sparrow	*Passerculus sandwichensis*	Resident	Omnivore	Ground		Non-Dependent	Native	Ground
Lincoln's Sparrow	*Melospiza lincolnii*	Resident	Omnivore	Ground		Obligate	Native	Ground
Song Sparrow	*Melospiza melodia*	Resident	Omnivore	Ground		Obligate	Native	Ground
Vesper Sparrow	*Pooecetes gramineus*	Nonbreed	Omnivore	Ground		Non-Dependent	Native	Ground
White-crowned Sparrow	*Zonotrichia leucophrys*	Nonbreed	Omnivore	Ground		Non-Dependent	Native	Shrub
Golden-crowned Sparrow	*Zonotrichia atricapilla*	Nonbreed	Omnivore	Ground		Non-Dependent	Native	Ground
Dark-eyed "Oregon" Junco	*Junco hyemalis thurberi*	Resident	Omnivore	Ground		Non-Dependent	Native	Ground
Black-headed Grosbeak	*Pheucticus melanocephalus*	Neotropical	Omnivore	Canopy	PIF 1	Dependent	Native	Tree
Blue Grosbeak	*Guiraca caerulea*	Neotropical	Omnivore	Ground		Obligate	Native	Shrub
Lazuli Bunting	*Passerina amoena*	Neotropical	Omnivore	Ground	PIF 1	Dependent	Native	Shrub
Western Meadowlark	*Sturnella neglecta*	Resident	Insectivore	Ground		Non-Dependent	Native	Ground
Yellow-headed Blackbird	*Xanthodephalus xanthocephalus*	Resident	Insectivore	Ground	PRBO 2	Marsh bird	Native	Reeds
Red-winged Blackbird	*Agelaius phoeniceus*	Resident	Insectivore	Ground		Non-Dependent	Native	Reeds
Tricolored Blackbird	*Agelaius tricolor*	Resident	Insectivore	Ground	PRBO 1, PIF 1	Marsh bird	Native	Reeds
Great-tailed Grackle	*Quiscalus mexicanus*	Resident	Omnivore	Ground		Non-Dependent	Native	Tree
Brewer's Blackbird	*Euphagus cyanocephalus*	Resident	Insectivore	Ground		Non-Dependent	Native	Coniferous Tree
Brown-headed Cowbird	*Molothrus ater*	Resident	Insectivore	Ground		Non-Dependent	Native	Tree
Hooded Oriole	*Icterus cucullatus*	Neotropical	Omnivore	Canopy	PIF 2B	Dependent	Native	Tree
Bullock's Oriole	*Icterus bullockii*	Neotropical	Omnivore	Canopy	PIF 1	Dependent	Native	Tree
Scott's Oriole	*Icterus parisorum*	Neotropical	Omnivore	Canopy		Non-dependent	Native	Tree
Purple Finch	*Carpodacus purpureus*	Resident	Granivore	Canopy		Non-Dependent	Native	Coniferous Tree
House Finch	*Carpodacus mexicanus*	Resident	Granivore	Ground		Non-Dependent	Native	Tree
Pine Siskin	*Carduelis pinus*	Resident	Granivore	Ground		Non-Dependent	Native	Coniferous Tree
American Goldfinch	*Carduelis tristis*	Resident	Granivore	Ground		Dependent	Native	Shrub
Lesser Goldfinch	*Carduelis psaltria*	Resident	Granivore	Ground	PIF 2A	Dependent	Native	Tree
Lawrence's Goldfinch	*Carduelis lawrencei*	Resident	Granivore	Ground	PIF 1	Non-Dependent	Native	Tree
House Sparrow	*Passer domesticus*	Resident	Granivore	Ground		Non-Dependent	Introduced	Cavity
								(Sheet 5 of 5)

[1]F = Federal, S = State, E = Endangered, T = Threatened; PRBO Birds of Special Concern priority levels 1, 2, or 3; PIF Tiers 1 and 2 only.